DOCUMENT RESUME

ED 273 639 SP 028 058

AUTHOR Figoni, Stephen F.
TITLE Central Cardiovascular Responses of Quadriplegic Subjects to Arm Exercise at Varying Levels of Oxygen Uptake.
PUB DATE 13 Apr 86
NOTE 11p.; Paper presented at the National Convention of the American Alliance for Health, Physical Education, Recreation and Dance (Cincinnati, OH, April 10-13, 1986). Supported by grants from the American Corrective Therapy Association and the Division of Rehabilitation-Education Services, University of Illinois, Urbana-Champaign.
PUB TYPE Speeches/Conference Papers (150) -- Reports - Research/Technical (143)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Cardiovascular System; *Disabilities; *Exercise; Males; Research Methodology
IDENTIFIERS *Oxygen Uptake Test

ABSTRACT

The purpose of this study was to assess selected central cardiovascular functions of spinal cord injured, quadriplegic subjects at varying levels of oxygen uptake (VO sub 2). Subjects included 11 untrained, male college students with C5, C6, or C7 complete quadriplegia and 11 able-bodied reference subjects. Exercise was performed on a Monark cycle ergometer modified for arm-cranking in the sitting position. Open-circuit spirometry was used to measure oxygen uptake. Impedance cardiography and ECG were utilized to measure stroke volume, heart rate, and ejection fraction. Results indicated that in quadriplegics, increases in VO sub 2 appear to be controlled primarily by 0 sub 2 extraction by peripheral tissues with very limited 0 sub 2 delivery capability. These findings support the hypothesis that the functional syndrome of quadriplegia produces a set of predictable "hypokinetic" circulatory responses to dynamic arm exercise. Tables and figures illustrate the data. (Author/JD)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

CENTRAL CARDIOVASCULAR RESPONSES OF QUADRIPLEGIC SUBJECTS TO ARM EXERCISE AT VARYING LEVELS OF OXYGEN UPTAKE

ED273639

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
S. F. Figoni
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Stephen F. Figoni

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
☐ This document has been reproduced as received from the person or organization originating it.
☐ Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

Physical Fitness Research Laboratory
Department of Physical Education
University of Illinois at Urbana-Champaign

Paper presented at the 1986 Convention of the American Alliance for Health, Physical Education, Recreation, and Dance (AAHPERD) in Cincinnati, OH on April 13, 1986.

Supported by grants from the American Corrective Therapy Association, Inc. and the Division of Rehabilitation-Education Services at the University of Illinois at Urbana-Champaign.

SP 028 058

ABSTRACT

The purpose of this study was to assess selected central cardiovascular functions of spinal cord injured, quadriplegic subjects at varying levels of oxygen uptake ($\dot{V}O_2$). Subjects included 11 untrained, male college students with C5, C6, or C7 complete quadriplegia and 11 able-bodied reference subjects. Exercise was performed on a Monark cycle ergometer modified for arm-cranking in the sitting position. Open-circuit spirometry was used to measure oxygen uptake.

Impedance cardiography and ECG were utililized to measure stroke volume (SV), heart rate (HR), and ejection fraction (EF). Calculated variables included cardiac output (CO), arteriovenous oxygen difference ($(a-\bar{v})O_2diff$), end diastolic volume (EDV), end systolic volume (ESV), and a myocardial contractile index (MCI). The variables were determined during seated rest, two levels of submaximal exercise, and maximal exercise on 2-4 different occasions. In quadriplegics, $\dot{V}O_2$ increased linearly with power output from 0.19 L/min at rest to 0.66 L/min at 23 watts. HR and $(a-\bar{v})O2diff$ increased linearly with $\dot{V}O_2$ from 74 bpm and 5.1 ml/100ml at rest to 122 bpm and 15.5 ml/100ml during maximal exercise. CO increased slightly from 3.86 to 4.34 l/min. SV, EDV, and EF decreased linearly with increasing VO_2, each ranging, respectively, from 54 ml, 72 ml, and 75% at rest to 36 ml, 53 ml, and 68% at maximal exercise. MCI and ESV did not change significantly, remaining at approximately 14 ohm/sec^2 and 18 ml, respectively. Unlike able-bodied subjects, HR and SV were inversely related ($r=-.77$, $p < .01$). In quadriplegics, increases in $\dot{V}O_2$ appear to be controlled primarily by O_2 extraction by peripheral tissues with very limited O_2 delivery capability. These findings support the hypothesis that the functional syndrome of quadriplegia produces a set of predictable "hypokinetic" circulatory responses to dynamic arm exercise.

PURPOSE AND HYPOTHESIS

The purpose of this study was to assess selected central cardiovascular (hemodynamic) functions of quadriplegic men and 11 able-bodied men at 4 levels of oxygen uptake.

Cervical spinal cord injury and its anatomical consequences were expected to produce a set of patterned physiological responses to dynamic arm exercise that may comprise a "hypokinetic circulatory syndrome" characteristic of C5-7 complete quadriplegic men.

Subjects

Experimental subjects included 11 untrained, male college students with C5, C6, or C7 complete quadriplegia secondary to cervical spinal cord injury. Their mean age, height, and weight were 27.1 yr, 178.4 cm, and 63.9 kg. A reference group of 11 able-bodied men of similar age, height, weight, and training status were also tested for comparison. All subjects completed informed consent procedures prior to testing. Quadriplegics obtained medical clearnce prior to testing.

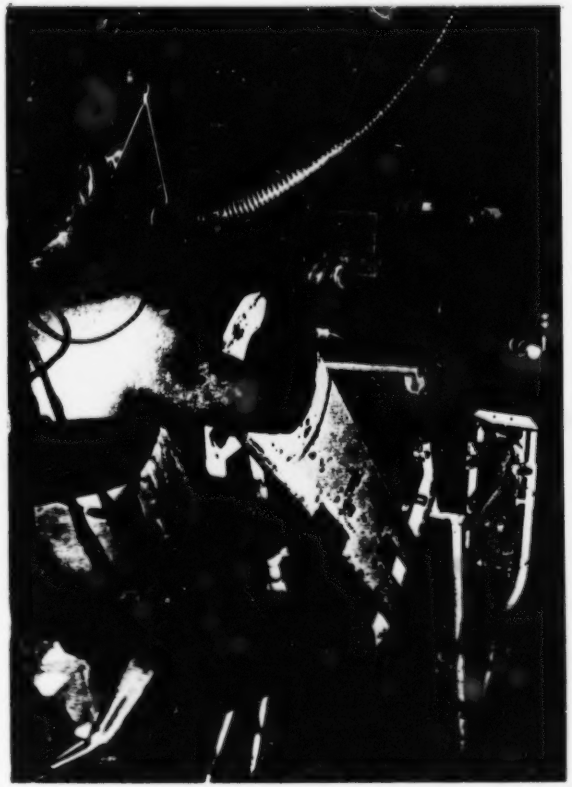
Procedures

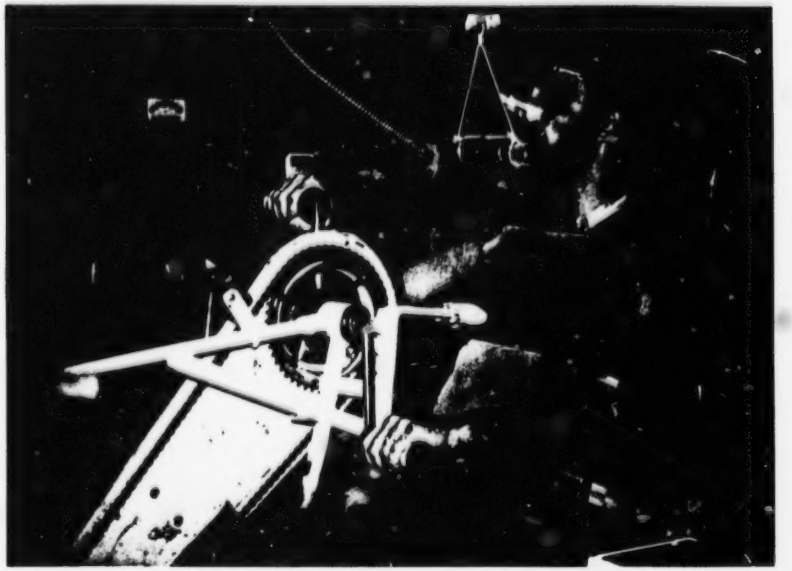
Four exercise tests were administered to each subject using a Monark cycle ergometer modified for arm-cranking in the sitting position. The first two preliminary tests were graded to assess physiological responses to a progressive series of power outputs from rest to maximum. During all tests, open-circuit spirometry was used to assess $\dot{V}O_2$; HR was monitored by ECG.

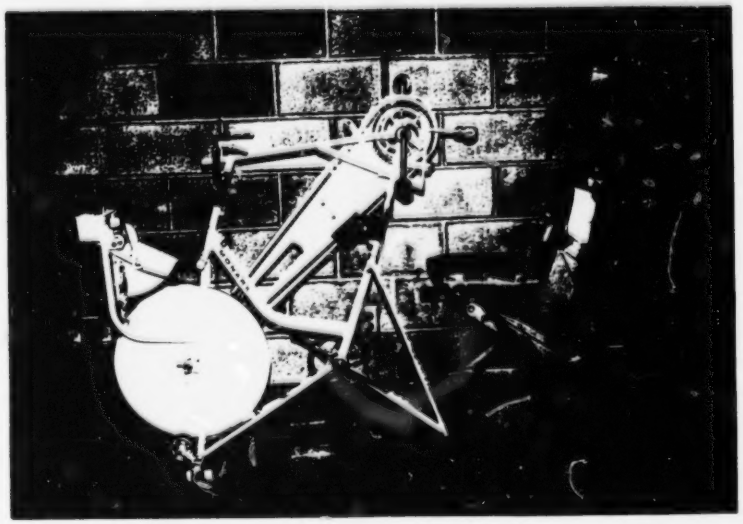
The second two exercise tests (see Figure 1) elicited relative metabolic loads of 0, 50, and 100 percent of $\dot{V}O_2$ reserve and an absolute load of $\dot{V}O_2$ = 0.5 L/min. "Percent $\dot{V}O_2$ Reserve," a scale of relative metabolic load, was defined as ($\dot{V}O_2$ observed - $\dot{V}O_2$ rest)/ ($\dot{V}O_2$ max - $\dot{V}O_2$ rest) x 100. Data were collected during five consecutive minutes of sitting rest (0% $\dot{V}O_2$ reserve). Two trials at 50% $\dot{V}O_2$ reserve and at $\dot{V}O_2$ = 0.5 L/min (submaximal exercise) performed, consisting of two 3-min exercise periods separated by one minute of rest. The power outputs necessary to elicit 50 and 100% of $\dot{V}O_2$ reserve and a $\dot{V}O_2$ of 0.5 L/min were based on the first two preliminary exercise tests. Finally, one trial of 3-min duration during maximal exercise (100% $\dot{V}O_2$ reserve) was performed.

Impedance cardiography was used to measure left ventricular stroke volume (SV) and ejection fraction (EF) immediately post-exercise. Calculated variables included cardiac output (CO), arteriovenous oxygen difference ($(a-\bar{v})O_2$dif), end diastolic volume (EDV), end systolic volume (ESV), and a myocardial contractile index (MCI).

FIGURE 1. ARM-CRANKING EXERCISE.







Tables 1 and 2 show the mean (± 1 SD) data for all subjects. Figure 2 illustrates these data.

1. HR and $(a-\bar{v})O_2$diff increased linearly with $\dot{V}O_2$. Maximal values for power output and $\dot{V}O_2$ are approximately 25-33% of values for able-bodied men. Maximal $(a-\bar{v})O_2$diff is very high, perhaps reflecting a peripheral training effect in the active musculature that allows very effective O_2 extraction from the blood by the active tissues in the absence of a very effective O_2 delivery system.

2. CO increases a slight amount, but is nearly constant, from rest through submaximal and maximal exercise, indicating very limited ability/necessity to circulate blood and deliver O_2. This unusual finding is consistent with previous findings of lack of a pressor response to exercise and limited maximal HR and the present finding of limited myocardial contractility, secondary to sympathetic decentralization of the heart and blood vessels below the level of spinal cord injury.

3. CO is maintained by an inverse relationship between HR and SV ($r=-.77$, $p < .01$). The increase in HR is approximately half of what occurs in able-bodied men.

4. MCI remainsconstant across rest and exercise conditions, suggesting a constant contractile state of the myocardium, slightly above the resting level for able-bodied men.

5. The decrease in EDV with exercise suggests very limited venous return from the lower body due to venous pooling in the legs and abdomen (secondary to vasomotor impairment and lack of the leg muscle pump). These may result in very low cardiac preload in the upright position and, consequently, very low SV and CO.

TABLE 1

MEAN (±1 SD) DATA FOR 11 QUADRIPLEGIC MEN

	OXYGEN UPTAKE (L/MIN)			
	.19±.02 (REST)	.42±.04	.51±.02	.66±.07 (MAX)
POWER OUTPUT (W)	0	10±2	15±2	23±5
PERCENT VO2 MAX	29±5	64±4	77±7	100
(a-v)O 2diff (ml/100ml)	5.1±5	10.4±1.0	12.4±1.8	15.5±2.5
CARDIAC OUTPUT (L/min)	3.86±.43	4.14±.54	4.20±.70	4.34±.71
HEART RATE (bpm)	74±10	95±9	105±7	122±7
EJECTION FRACTION (%)	75±5	71±5	70±6	68±7
MYOCARDIAL CONTRACTILE INDEX (ohms/sec ^{2})	14.2±2	15±2	14±2	15±2
END DIASTOLIC VOLUME (ml)	72±13	71±5	58±9	53±8
END SYSTOLIC VOLUME (ml)	19±6	18±3	18±5	17±5

TABLE 2

MEAN DATA (± 1 SD) FOR 11 ABLE-BODIED MEN

	OXYGEN UPTAKE (L/min)			
	.25±.03 (REST)	.51±.02	1.04±.11	1.81±.26 (MAX)
POWER OUTPUT (W)	0	13±3	53±7	87±12
PERCENT VO2 MAX	14±2	29±6	58±5	100
(a-v)O 2diff (ml/100ml)	6.0±.8	8.8±1.4	12.0±1.0	14.2±1.6
CARDIAC OUTPUT (L/min)	4.30±.61	5.88±.73	8.74±1.03	12.81±1.04
HEART RATE (bpm)	65±1	78±10	114±11	171±10
STROKE VOLUME (ml)	68±1	77±13	78±11	76±6
EJECTION FRACTION (%)	64±2	70±3	76±2	81±3
MYOCARDIAL CONTRACTILE INDEX (ohms/sec ^{2})	12±1	14±2	22±3	35±6
END DIASTOLIC VOL. (ml)	106±16	111±21	102±16	94±8
END SYSTOLIC VOL. (ml)	38±8	34±9	25±5	16±4

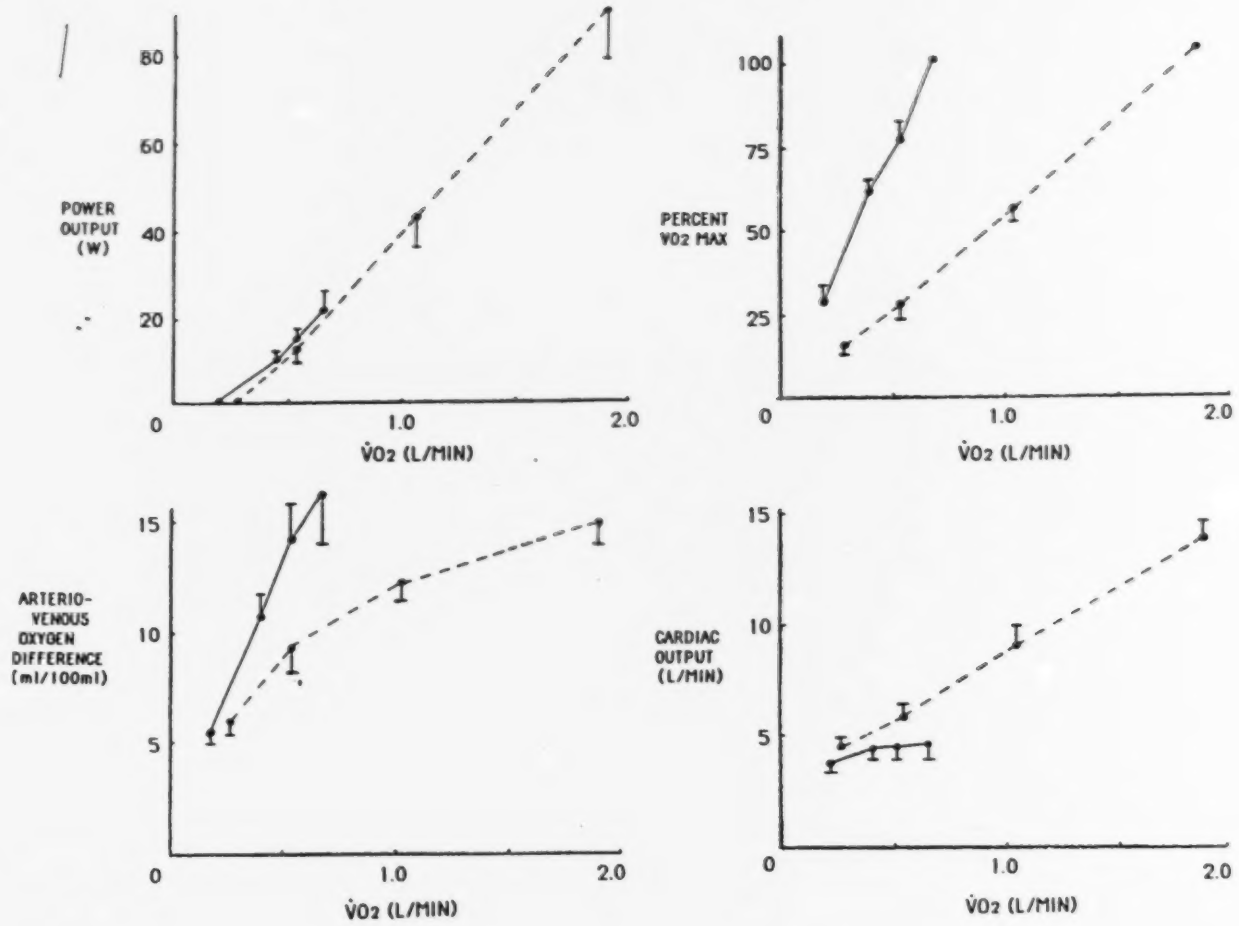
FIGURE 2.

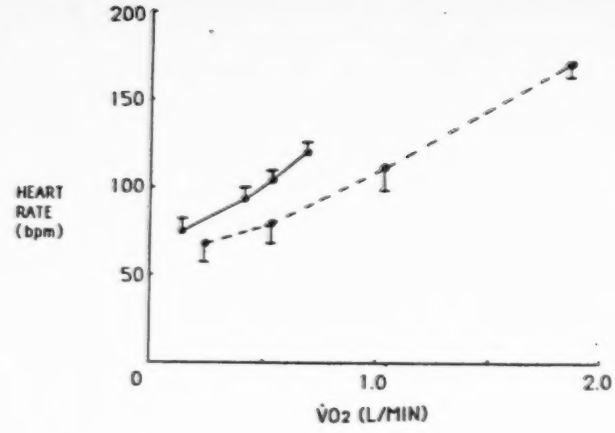
GRAPHS OF PHYSIOLOGICAL VARIABLES
PLOTTED AS A FUNCTION OF OXYGEN UPTAKE.

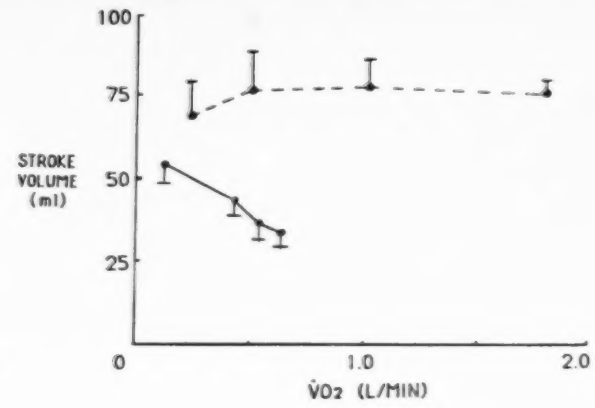
_____ = Quadriplegics (n=11)

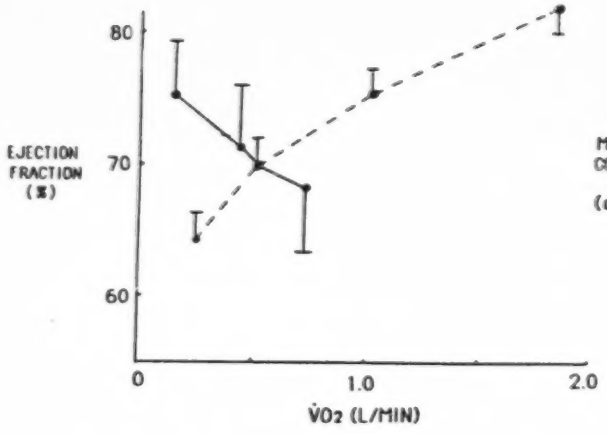
- - - - - - - - = Able-Bodied (n=11)

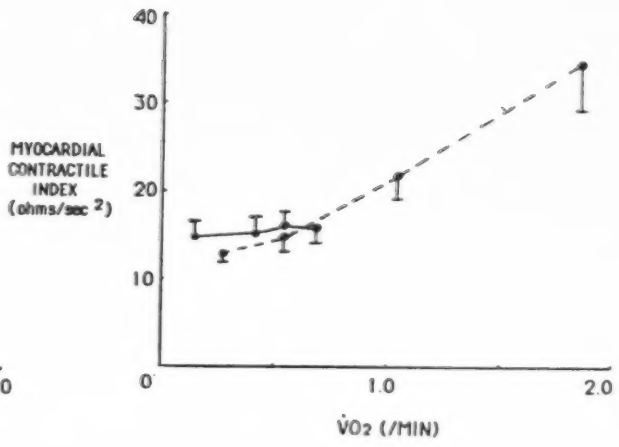
Points represent mean values (± 1 SD).

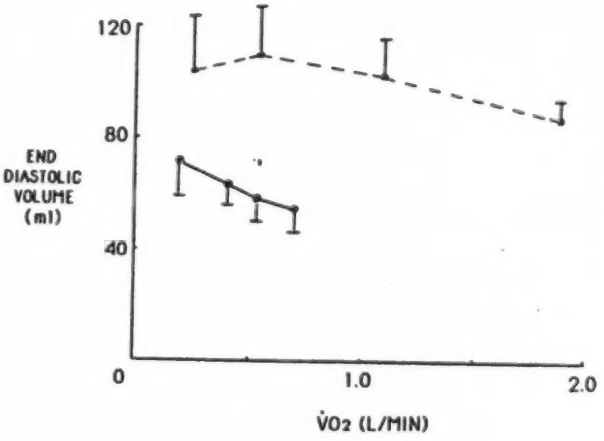


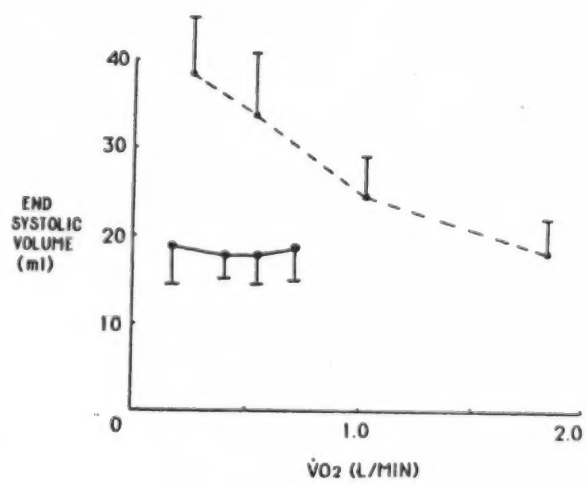

HEART RATE (bpm)
200
150
100
50
0
1.0
2.0
V̇O2 (L/MIN)


STROKE VOLUME (ml)
100
75
50
25
0
1.0
2.0
V̇O2 (L/MIN)


EJECTION FRACTION (%)
80
70
60
0
1.0
2.0
V̇O2 (L/MIN)

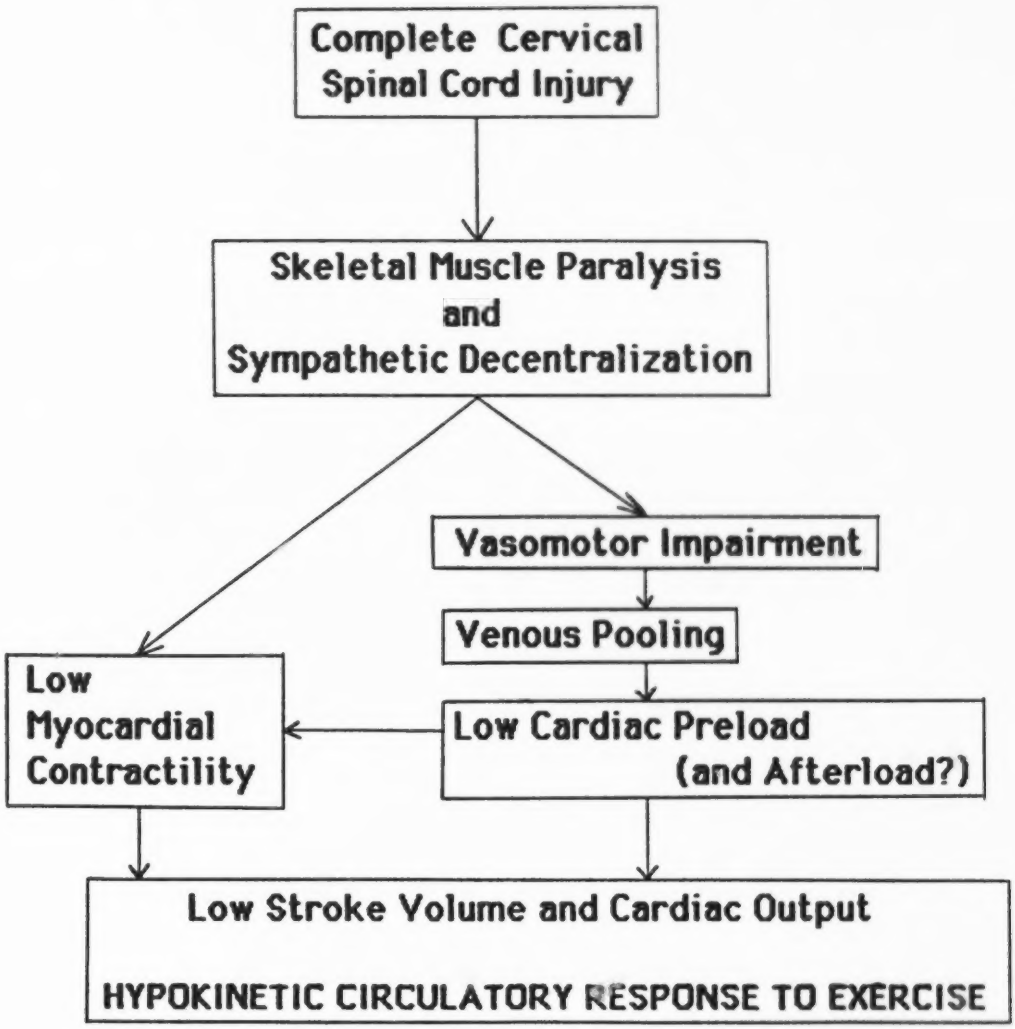

MYOCARDIAL CONTRACTILE INDEX (ohms/sec 2)
40
30
20
10
0
1.0
2.0
V̇O2 (/MIN)


END DIASTOLIC VOLUME (ml)
120
80
40
0
1.0
2.0
V̇O2 (L/MIN)


END SYSTOLIC VOLUME (ml)
40
30
20
10
0
1.0
2.0
V̇O2 (L/MIN)

CONCLUSION

The findings support the hypothesis that the functional syndrome of C5-6-7 complete quadriplegia produces a "hypokinetic circulatory syndrome" in response to dynamic arm exercise, according to the following model.


Complete Cervical Spinal Cord Injury
Skeletal Muscle Paralysis and Sympathetic Decentralization
Vasomotor Impairment
Venous Pooling
Low Myocardial Contractility
Low Cardiac Preload (and Afterload?)
Low Stroke Volume and Cardiac Output
HYPOKINETIC CIRCULATORY RESPONSE TO EXERCISE